musicians' hearing program

BY BRIAN J. FLIGOR AND FRANK WARTINGER

Patients involved in the creation and consumption of music stand to benefit most from the services of audiologists.

In the words of Benj Kanters, associate chair of the Audio Engineering Program at Columbia College in Chicago, Illinois, "musicians and audio engineers need an audiologist like everyone else needs a dentist."[1] While Benj is not an audiologist, he can teach physiology of the hearing mechanism better than most (the authors included). He is also a wealth of knowledge in the field of music production—both live and recorded. And to his credit, he teaches his students that the key to optimal sound recording and production is not how many teeth are rattled but how exquisitely the natural experience of the music is reproduced after it has been created. In the authors' experience, your typical audio engineer has a deep appreciation for the Fletcher-Munson curves, perhaps beyond that of most audiologists.

As with most patients, there is a wide range of technical and auditory savvy in musicians and audio engineers. Often these are the patients who seem to challenge the technical abilities of the audiologist when conducting an audiological evaluation or fitting personal amplification. While potentially frustrating, these patients stand to benefit most from the services of audiologists. This article is presented as a concept for how these services might be delivered to a population that is in dire need of hearing loss prevention and management of noise/music-induced hearing disorders. It is the goal of the Musicians' Hearing Program (MHP) at Children's Hospital Boston Diagnostic Audiology Program to provide such prevention and management services to those involved in the creation and consumption of music.

Table 1. Total Audience Exposure

Leq (dBA)	105
Time (hr)	4
Noise dose*	5000%

Table 2. Total Crew Exposure (four-hour show, soundcheck, and setup)

Leq (dBA)	99
Time (hr)	7
Noise dose*	2198%

Table 3. Total Audience Exposure with Hypothetical Reduction in Exposure from Use of Different Hearing Protection Devices

Leq (dBA)	105
Time (hr)	4
Noise dose*	5000%
w/ ER-9 (–9 dB)	629%
w/ ER-15 (–15 dB)	158%
w/ ER-25 (–25 dB)	16%
w/ foam (–20 dB)	50%

Table 4. Total Crew Exposure with Hypothetical Reduction in Exposure from Use of Different Hearing Protection Devices

Leq* (dBA)	99
Time (hr)	7
Noise dose*	2198%
w/ ER-9 (–9 dB)	277%
w/ ER-15 (–15 dB)	70%
w/ ER-25 (–25 dB)	7%
w/ foam (–20 dB)	22%

Note: Leq = typical five-minute equivalent continuous sound level in A-weighted decibels.

*Damage risk criterion for determining "noise dose" = 85 dBA for 8 hr Leq, 3 dB exchange rate.

Background

Music- (and noise-) induced hearing disorders encompass problems in the auditory system beyond the stereotypical "4k Hz/noise notch." Seldom would a patient enter an audiologist's practice complaining of difficulty hearing soft signals around 4k Hz. More typically, the musician or audio engineer will confide in the clinician difficulties with chronic ringing in their ears and perhaps decreased tolerance of louder sound. Hearing problems for this population are deeply personal, and there is reasonable fear that public disclosure of hearing disorders will impair their employability because "who wants a recording engineer whose ears are damaged?"

While easy to quantify, noise-induced permanent threshold shift (NIPTS) is not the most overt difficulty experienced by those involved in music production. If we think about the perceptual consequences of a mild-to-moderate sensorineural notch at 4k Hz, it is inconsequential when the average levels are roughly 85–90 dBA and the dynamic range of a music recording is 30–40 dB. Given the equal loudness contours of the Fletcher-Munson curves, it makes sense that even in the impaired cochlea, when the sounds are sufficiently intense above the threshold of audibility, sound will be just as loud to the person with sensorineural hearing loss as the person with normal hearing.

Of potentially greater consequence than NIPTS are unremitting, clinically significant tinnitus, hyperacusis (loudness intolerance), and/or diplacusis (collectively described as "pitch perception problems"), which are also consequences of damage to the auditory system from intense sound exposure. Prevention of these latter three music-induced hearing disorders (MIHDs) is a primary example of the necessity of audiologists in the service of musicians and audio engineers. When these disorders have not been prevented, it is the audiologist who is uniquely qualified to mitigate the negative effects of the MIHD.

The Elements of a Hearing Loss Prevention Program

Generally, a comprehensive hearing loss prevention program (HLPP) includes:

1. Sound exposure survey (aka "noise survey")
2. Engineering and administrative controls
3. Audiometric monitoring

4. Education and motivation

5. Hearing protection devices

While these concepts are typically viewed through the perspective of industrial audiology, they can be applicable for occupational (and nonoccupational) exposures to intense levels of music.

Sound Exposure Survey

An integral piece of a HLPP is the sound exposure survey: how does one know if the intense sound is in fact hazardous to hearing unless there is good data to support this assertion? In many ways, without evidence suggesting the exposure poses a risk to hearing, the other elements of the HLPP may be moot.

Recently, the authors were invited to the Bamboozle Road Show, at the Comcast Center in Mansfield, Massachusetts, by two of the headlining acts. This tour featured seven bands that can be described primarily as punk/alternative rock acts on the main stage of the 14,000-seat amphitheater. We made sound level and dosimetry measurements in the audience and also to the left of and behind the stage (near the crew). These results are summarized in TABLES 1 AND 2.

The National Institute for Occupational Safety and Health (NIOSH) has adopted a damage risk criterion (DRC) that recommends exposure levels not exceed 85 dBA for an eight hour equivalent continuous level, with a time-intensity trading ratio (exchange rate) of 3 dB (NIOSH, 1998). Such a maximum recommended exposure would be a "100 percent noise dose." TABLE 1 indicates that for an attendee who remained in the audience for the four hour duration of the main stage acts, that participant would have exceeded the NIOSH recommended exposure limit by 50 times. A crew member stationed backstage for the duration of the soundcheck and performance would exceed his or her allowable noise dose by 22 times. Unquestionably, unprotected exposures such as these examples should be avoided, as they constitute a risk to hearing health. For the seldom concert-goer, an overexposure of 5,000 percent is not likely to cause immediate, permanent hearing damage,

but this would contribute to that individual's lifetime cumulative sound exposure. In some individuals highly susceptible to intense sound exposure, it is possible that a 5000 percent dose could result in MIHD. For the crew member overexposed as often as 200 shows per year, even though the relative exposure is considerably less backstage than in the audience, the repetitive nature of the exposure puts this individual at much greater risk than the infrequent attendee.

Admittedly, the majority of musicians do not hire an audiologist or industrial hygienist to conduct a sound exposure survey to determine whether or not hazard exists. Audiologists often need to base their understanding of the levels of risk on published reports of such exposures. A good rule of thumb is that the very occasional concert-goer (attending perhaps two concerts per year) is at low risk for MIHD from concerts relative to the other noisy events encountered. Some use of hearing protection would be reasonable, but enrollment in a formal HLPP may not be warranted. Regular concert attendees (attending one or more concerts per month) should give consideration to following elements of HLPP, such as regular audiological evaluations and use of hearing protection. Which elements to incorporate for these more avid fans are best determined under the direction of an audiologist. For those engaged in regular production or performance (that is, the crew or the musicians), HLPP is essential to the longevity of their careers and long-term quality of life.

Engineering and Administrative Controls

As we have established risk in our sound exposure survey example, there are many opportunities to reduce risk that do not involve the use of hearing protection devices. Since engineering controls, by definition, address the problem at the source, thereby reducing the need for further controls, they should be applied first and most diligently. The most straightforward solution is physical removal of the individual from the high noise location, which is often accomplished by placing the personnel in another room or isolated location while relying on an audio/video feed for interaction. Utilizing shifts as "resting periods" away from high noise is another common solution found in the

Boys Like Girls on stage. The speaker cabinets that line the back of the stage, to the left and right of John O'Keefe, drummer, are not connected, they are for show. The signal from the instruments runs directly to the Front of House (FOH) engineer and monitor engineer, for broadcast to the audience through FOH speakers, and back to the musicians according to their listening needs through their in-ear monitors.

industry. The "green room" is a common entertainment industry application of these solutions. Finally, the reduction of onstage levels is beneficial for crew and musicians alike, not to mention potentially advantageous to the sound quality for the audience, and can be accomplished with Plexiglas barriers around the drums, reduction of on-stage amplifiers, and in-ear monitors used by musician.

Onstage sound reinforcement delivered through floor "wedge" monitors is one of the most significant contributors to stage volume, but in order for musicians to hear themselves and each other, and therefore monitor and maximize their performance, adequate monitoring is essential. In our sound exposure survey example, the onstage levels were so low (99 dBA) relative to the audience (105 dBA) because nearly all the musicians were using in-ear monitors. Employing in-ear monitors reduces the levels of the sound field of the stage: there may be no floor monitors, leaving the audience, house main loudspeakers, and drums as the only significant sound sources.

Employing in-ear monitors reduces the levels of sound field on the stage.

However, the use of in-ear monitors creates a challenge to the sound exposure survey because in order to assess the free-field equivalent exposure of the musician using in-ear monitors, the audiologist would need to conduct probe-microphone measures and correct for the ear canal resonance to approximate the levels the musician chooses at which to monitor. Alternatively, one manufacturer, Sensaphonics, Inc., does have a device, the dB Check™, that provides the free-field equivalent sound

Safety and rock-and-roll are like oil and water; they don't really mix.

levels if the musician is using a Sensaphonics in-ear monitor. Citing Federman and Ricketts (2008), Michael Santucci, AuD, precisely conveyed in a recent interview (Santucci, 2010) that musicians will often choose hazardous levels unless guided by an expert, i.e., the audiologist, how to use them correctly and safely, rather than as a device capable of contributing to MIHD. This guidance begins with accurately reporting the chosen listening levels of the musician through the in-ear monitors.

Audiometric Monitoring

In industries regulated by the Occupational Safety and Health Administration (OSHA), noise-exposed workers enrolled in HLPPs must have their hearing tested annually. One could argue that the hearing needs of musicians and music producers are more exquisite than are those of people employed in manufacturing, given that it is the musician's/producer's hearing that is responsible for their job performance and livelihood. So how many musicians/producers have their hearing tested annually?

For those music industry professionals enrolled in an HLPP in the MHP, the standard recommendation is annual audiometric evaluation that includes comprehensive audiometry (air, bone, word recognition), distortion product otoacoustic emissions (DPOAEs), immittance, and a tinnitus inventory (if any tinnitus is reported during the history). The intent of the comprehensive audiometry is to establish baseline pure-tone thresholds and compare thresholds each year for surveillance of a significant threshold shift.[2] Additionally, the audiologist should remain vigilant to otologic problems unrelated to MIHD and make appropriate medical referrals as warranted. It has been the authors' experience, and it has been reported in the literature (Helleman et al, 2010), that OAEs can be an indicator of damage from sound exposure before such damage is evident on the pure-tone audiogram. The baseline DPOAEs establish a

FOH during Boys Like Girls, headlining the Bamboozle Road Show 2010. The best seats in the house for sound. Note the Radio Shack sound level meter with the red tape on the mixer board. This sound level meter showed 104 dBA in this photo.

baseline against which DPOAE measures are compared at future evaluations. Each clinic should establish its own test-retest reliability for their DPOAEs, so that a significant change from baseline DPOAEs can be detected on future evaluations of the musician. Finally, as noted in the background section above, hearing disorders other than NIPTS are likely of greater concern to the music industry professional. During the history, every MHP patient is asked about his or her experience with ringing, buzzing, or hissing noises in their ears, ability to tolerate loud sound, and potential distortion of sound in one or both ears. Any patient whose history is positive for these screening questions is evaluated for tinnitus, hyperacusis, and/or diplacusis.

Education and Motivation

It has been well established in the community of hearing conservation professionals that education and motivation are the most effective HLPP elements at preventing hearing loss. The authors have encountered a wide range of attitudes and education related to hearing loss prevention in music industry professionals. Some are highly educated and/or highly motivated, while others are resolutely cavalier.

Quoting again from Michael Santucci's interview (2010, page 14), "it's like Steven Tyler of Aerosmith told me, 'Michael, safety and rock-and-roll are like oil and water; they don't really mix.' So I said, 'That's true, Steven. But how about rock-and-roll and quality of life? Because I know you're into that, and if your hearing stinks, so does your quality of life.' That, he could relate to."

In efforts to connect to a sensitive population, attempts should be made to take the theory behind clinical practice and bring it literally into their world. The musician's world is one of performance with high personal standards, which relies on minute modifications in execution and perception to maintain a competitive edge, not unlike a trained athlete. Any barrier impeding that performance edge will be rejected. We should critically evaluate all aspects of our service and consider if these pose a barrier to optimal performance, given that the patient's acceptance of the HLPP is crucial for their livelihood.

The real issue is the overlying attitude toward risk and damage. The old adage is "no pain, no gain," so the thinking may go something like this: since a good run leaves you sore, and a good night out can make your morning drag, shouldn't a good musical event leave your ears worn, dull, and reeling with tinnitus? Notwithstanding research into the toughening effects of moderate levels of noise pre–intense sound exposure, the "no pain, no gain"

mindset can be taken too far, and meeting the music industry professional on his or her level could help them take ownership over their hearing health. To do otherwise, to forget about issues of performance for the sake of long-term hearing health, begs for rebellion against the "preachiness" of the do-gooder audiologist.

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Hearing Protection Devices

Of the five elements of the HLPP, hearing protection devices (HPDs) are last on the list for good reason. HPDs are a last line of defense. They are an acknowledgement that the first four elements have failed to prevent risk for MIHD. This point accepted, HPDs are an integral part of the HLPP.

So which HPD is the right one for your patient? Are they an occasional concert attendee or a music industry professional? Quoting the National Hearing Conservation Association, "the right kind of earplug is the one you will use" (www.hearingconservation.org). As noted in the sound exposure survey, an occasional concert attendee in the audience at the Bamboozle Road Show for the full duration of the main stage acts would have greatly exceeded the recommended exposure level. Some hearing protection, used properly, would have significantly reduced the exposure. For the more avid concert-goer who desires better sound quality than is offered by foam earplugs, Musicians' Earplugs™ are a reasonable and relatively economical alternative to nonflat frequency attenuating earplugs. Shown in TABLE 3 AND 4 are the results of the sound exposure survey for the audience and crew, with hypothetical noise dose when using different HPDs.

The authors caution the reader against overinterpreting the ER-15 results, thinking it is inadequate for audience because it exceeds 100 percent noise dose. Consider if a given audience member stays for the full four hours inside the venue (do they ever get food or use the bathroom?). Also consider that their weekly exposure is not averaged over a eight-hour Leq but a 40-hour Leq, in which case the protected weekly sound exposure would be much less than 158 percent (it would, in fact, be 32 percent, assuming no other significant exposure occurs).

Finally, just because Musicians' Earplugs are marketed by a lab as being "flat" (i.e., theoretically the attenuation at all frequencies is the same and equal to the 9, 15, or 25 dB per the filter rating), this does not mean every earplug is indeed flat. Just as we do with hearing aid fittings, the audiologist must verify the attenuation in the ear canal (which can easily be done with probe microphone measures).

Management of MIHD

The focus of this article is not on the management of MIHD but perhaps rather on evaluation for and prevention of MIHD. However, when MIHD happens, the audiologist is uniquely qualified to manage the negative auditory consequences.

Both NIPTS and tinnitus can be addressed in part with personal amplification. The authors stress that hearing aid programming for optimizing spoken communication is not appropriate for music (especially live music) as an input. Not only is the frequency content and dynamic range more complex for music than for speech, the purpose of listening is fundamentally different: speech is primarily for eliciting and exchanging ideas, whereas music is primarily for eliciting and exchanging emotions. The interested reader is referred to writings by Marshall Chasin, AuD, and Mead Killion, PhD, who have covered this topic extensively.

Also of Interest

"Addressing Life's Issues and Severe-to-Profound Hearing Loss Through Music and Painting: Interview with Randy Rutherford"

Log in to www.audiology.org and search keyword "Rutherford."

Tinnitus management is beyond the scope of this article, but those engaged in tinnitus management in their practice who see music industry professionals with tinnitus are urged to consider the guilt that might be associated with this auditory affliction: the musician with tinnitus may feel a deep sense of responsibility for having caused his or her tinnitus. One of the most healing things the audiologist can say to the musician tinnitus patient is, "it's not your fault."

Hyperacusis and diplacusis may be exceedingly difficult to manage in a way that allows the music industry professional to continue in their chosen profession. Notwithstanding the differences between hypersensitivity to loud sound and misophonia, some desensitization of loud sound, coupled with appropriate use of HPDs (especially HPDs that do not overattenuate) is a start. Those with diplacusis may be able to turn to technological interventions (such as auto-tuners). In the case of diplacusis monauralis (i.e., one ear is afflicted), the musician can be taught which ear to attend to for pitch matching.

Conclusion

Performing cerumen management and taking earmold impressions on a tour bus or in the dressing room are perhaps not typical activities in the practice of audiology. Whether providing services at the concert venue or in the audiologist's clinic, the opportunity presents for the audiologist to promote a healthier hearing lifestyle to a sensitive group who needs the audiologist's services. Likely, the audiologist will find kindred spirits in those who love sound as much as the audiologist himself or herself, maybe for the same or for different reasons. And just because these sound exposures are unregulated by OSHA does not mean they are inconsequential or non occupational. In fact, when there is no regulation (as the authors believe should be the case in this industry), it is even more important for the health-care provider to promote the HLPP, particularly education and motivation, as a means to preserving the sense of hearing that is most valuable, and most at risk, in this population.

Brian J. Fligor, ScD, is director of diagnostic audiology at Children's Hospital Boston and an instructor in otology and laryngology at Harvard Medical School.

Frank Wartinger, BM, is an audiology extern at Children's Hospital Boston.

Notes

1. For more details on the profession of audio engineering, visit the Audio Engineering Society Web site at www.aes.org.

2. For more on standard/significant threshold shifts (STSs), please refer to NIOSH, 1998.

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